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0406690.8

24 MAR 2004

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Pursuit Dynamics plc
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Patents ADP number *(if you know it)*

8333072002

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

Mist Generator

5. Name of your agent *(if you have one)*

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
UK	0404230.5	26/2/04
UK	0405363.3	10/3/04

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Continuation sheets of this form	
Description	27
Claim(s)	
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Signature(s) MM Date 24/3/04

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

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Mist Generator

This invention relates to a mist generator

The present invention has reference to an apparatus and method for the generation of a liquid droplet mist with application to, but not restricted to, water mist generation for fire extinguishing, suppression and control. Hereinafter the present invention will be described with reference to the use of water but any other liquid can be used specific to the application. For example, for fire suppression any non-flammable liquid which absorbs heat when it vaporises may be used.

It is well known in the art that there are three major contributing factors required to maintain combustion. These are known as the fire triangle, i.e. fuel, heat and oxygen. Conventional fire extinguishing and suppression systems aim to remove or at least minimise at least one of these major factors. Typically fire suppression systems use inter alia water, CO2, Halon, dry powder or foam. Water systems act by removing the heat from the fire, whilst CO2 works by displacing the oxygen.

Another aspect of combustion is known as the flame chain reaction. The reaction relies on free radicals that are created in the combustion process and are essential for its continuation. Halon operates by attaching itself to the free radicals and thus preventing further combustion by interrupting the flame chain reaction.

The major disadvantage of water systems is that a large amount of water is usually required to extinguish the fire. This presents a first problem of being able to store a sufficient volume of water or quickly gain access to an adequate supply. In addition, such systems can also lead to damage by the water itself, either in the immediate region of the fire, or even from water seepage to adjoining rooms. CO2 and Halon systems have the disadvantage that they cannot be used in environments where people are present as it creates an atmosphere that becomes difficult or even impossible for people to breathe in. Halon has the further disadvantage of being toxic

and damaging to the environment. For these reasons the manufacture of Halon fire suppression systems is being banned in most countries.

To overcome the above disadvantages a number of alternative systems utilising liquid mist have emerged. The majority of these utilise water as the suppression media, but present it to the fire in the form of a water mist. A water mist system overcomes the above disadvantages of conventional systems by using the water mist to reduce the heat of the vapour around the fire, displace the oxygen and also disrupt the flame chain reaction. Such systems use a relatively small amount of water and are generally intended for class A and B fires, and even electrical fires.

Current water mist systems utilise a variety of methods for generating the water droplets, using a range of pressures. A major disadvantage of many of these systems is that they require a relatively high pressure to force the water through injection nozzles and/or use relatively small nozzle orifices to form the water mist. Typically these pressures are 20bar or greater. As such, many systems utilise a gas-pressurised tank to provide the pressurised water, thus limiting the run time of the system. Such systems are usually employed in closed areas of known volume such as engine rooms, pump rooms, and computer rooms. However, due to their finite storage capacity, such systems have the limitation of a short run time. Under some circumstances, such as a particularly fierce fire, or if the room is no longer sealed, the system may empty before the fire is extinguished. Another major disadvantage of these systems is that the water mist from these nozzles does not have a particularly long reach, and as such the nozzles are usually fixed in place around the room to ensure adequate coverage.

Conventional water mist systems use a high pressure nozzle to create the water droplet mist. Due to the droplet formation mechanism of such a system, and the high tendency for droplet coalescence, an additional limitation of this form of mist generation is that it creates a mist with a range of water droplet sizes. It is known that water droplets of approximately 40-50μm in size provide the optimum compromise

for fire suppression for a number of fire scenarios. For example, a study by the US Naval Research Laboratories found that a water mist with droplets less than 42μm in size was more effective at extinguishing a test fire than Halon 1301. A water mist comprised of droplets in the approximate size range of 40-50μm provides an optimum compromise of having the greatest surface area for a given volume, whilst also providing sufficient mass to project a sufficient distance and to also penetrate into the heat of the fire. The majority of conventional water mist systems only manage to achieve a low percentage of the water droplets in this key size range.

An additional disadvantage of the conventional water mist systems, generating a water mist with such a wide range of droplet sizes, is that the majority of fire suppression requires line-of-sight operation. Although the smaller droplets will tend to behave as a gas the larger droplets in the flow will themselves impact with these smaller droplets so reducing their effectiveness. A mist which behaves more akin to a gas cloud has the advantages of reaching non line-of-sight areas, so eliminating all hot spots and possible re-ignition zones. A further advantage of such a gas cloud behaviour is that the water droplets have more of a tendency to remain airborne, thereby cooling the gases and combustion products of the fire, rather than impacting the surfaces of the room. This improves the rate of cooling of the fire and also reduces damage to items in the vicinity of the fire.

An object of the present invention is to provide a water mist generator having an improved performance than water mist systems currently available.

According to a first aspect of the present invention a mist generator includes a body provided with an inlet for the introduction of a transport fluid and an outlet for the discharge of a dispersed droplet flow mixture, the inlet leads to a first chamber which in turn leads to a second chamber of substantially circumscribing form which leads to a first nozzle substantially circumscribing and opening into a passage, the passage between the first nozzle and the outlet forming a mixing chamber section, the first chamber also leads to a second nozzle located on, or parallel to, the axis of the body

and opening into the passage, a fluid inlet for the introduction of a working fluid leads to a fluid nozzle substantially circumscribing and opening into the passage between the first nozzle and the outlet, the nozzles being so disposed and configured that in use a droplet flow regime is created within the mixing chamber by the introduction of transport fluid and working fluid.

The transport fluid is preferably a compressible fluid and may be a gas or vapor, for example steam, which may be introduced in either a continuous or discontinuous manner.

According to a second aspect of the present invention a mist generator includes a body provided with an inlet for the introduction of steam and an outlet for the discharge of a dispersed droplet flow mixture, the inlet leads to a first chamber which in turn leads to a second chamber of substantially circumscribing form which leads to a first nozzle substantially circumscribing and opening into a passage, the passage between the first nozzle and the outlet forming a mixing chamber section, the first chamber also leads to a second nozzle located on, or parallel to, the axis of the body and opening into the centre of the mixing chamber, a fluid inlet for the introduction of a working fluid leads to a fluid nozzle substantially circumscribing and opening into the passage between the first nozzle and the outlet, the nozzles being so disposed and configured that in use a droplet flow regime is created within the mixing chamber by the introduction of steam and working fluid.

Hereinafter the first nozzle will be referred to as the primary nozzle, and the second nozzle will be referred to as the secondary nozzle.

The mist generator may be provided with one or more fluid inlets, for example for the introduction of a liquid or liquids, and/or a gas or gasses, and/or a powder or powders, provided in the passage intermediate the transport fluid nozzles and the outlet. The fluid inlet or inlets may circumscribe the passage and may therefore be

of annular form and may be located upstream and/or downstream of and/or coincident with the primary nozzle for the transport fluid or steam.

The working fluid, introduced into the unit to be mixed and dispersed into a droplet form, may be a liquid, for example water, a gas, for example air, a mixture of a gas and a liquid, or may be a powder or mixture of powder and liquid and/or gas. In some applications the gas may be an inert gas.

The mechanism of the present invention primarily relies on the momentum transfer between the transport fluid and the working fluid, which provides for shearing of the working fluid on a continuous basis by shear dispersion and/or dissociation, plus provides the driving force to propel the generated mist out of the outlet. However, when the transport fluid is a hot compressible gas, for example steam, i.e. the transport fluid is of a higher temperature than the working fluid, it is thought that this mechanism is further enhanced with a degree of mass transfer between the transport fluid and the working fluid as well. Again, when the transport fluid is hotter than the working fluid the heat transfer between the fluids and the resulting increase in temperature of the working fluid further aids the dissociation of the liquid into smaller droplets by reducing the viscosity and surface tension of the liquid.

The intensity of the shearing mechanism, and therefore the size of the droplets created, and the propelling force of the mist is controllable by manipulating the various parameters prevailing within the system when operational. Accordingly the flow rate, pressure and quality, e.g. in the case of steam the dryness, of the transport fluid may be regulated to give the required intensity of shearing and droplet formation. Similarly, the flow rates, velocities and temperatures of the fluids which make up the working fluid, which are either entrained or pumped into the mist generator, may be regulated to give the required intensity of shearing and droplet formation.

The passage may be of any convenient cross-sectional shape suitable for the particular application of the mist generator. The passage shape may be circular, rectilinear or any intermediate shape, for example curvilinear.

The primary nozzle may be located as close as possible to the projected surface of the working fluid, in practice and in this respect a knife edge separation between the transport fluid or steam and the working fluid stream or streams may be of advantage in order to achieve the requisite degree of interaction. The angular orientation of the nozzle with respect to the flow of the working fluid stream or streams is of importance and may be shallow.

In some embodiments of the present invention a series of primary and fluid nozzles is provided lengthwise of the passage and the geometry of the nozzles may vary from one to the other dependent upon the effect desired. For example, the angular orientation may vary one to the other. The nozzles may have differing geometries in order to afford different effects, i.e. different performance characteristics, with possibly differing parametric steam conditions. For example some nozzles may be operated for the purpose of initial mixing of different liquids and gases whereas others are used simultaneously for additional droplet breakup or flow directionalisation. Each nozzle may have a mixing chamber section downstream thereof. In the case where a series of nozzles is provided the number of operational nozzles is variable.

The primary nozzle may be of a form to correspond with the shape of the passage and thus for example a circular passage would advantageously be provided with an annular nozzle circumscribing it. The term 'annular' as used herein is deemed to embrace any configuration of nozzle or nozzles that circumscribe the passage of the mist generator.

In the case of a rectilinear passage, which may have a large width to height ratio, nozzles would be provided at least on each transverse wall, but not necessarily on the

sidewalls, although the invention optionally contemplates a full circumscription of the passage by the nozzles irrespective of shape.

The or each primary nozzle may be continuous or may be discontinuous in the form of a plurality of apertures, e.g. segmental, arranged in a circumscribing pattern that may be circular. In either case each aperture may be provided with helical vanes formed in order to give in practice a swirl to the flow of the transport fluid. Alternatively swirl may be induced by introducing the transport fluid into the mist generator in such a manner that the transport fluid flow induces a swirling motion into and out of the primary nozzle or nozzles. For example, in the case of an annular primary nozzle, and with steam as the transport fluid, the steam may be introduced via a tangential inlet off-centre of the axial plane, thereby inducing swirl in the second chamber before passing through the primary nozzle or nozzles. As a further alternative the primary nozzle may circumscribe the passage in the form of a continuous helical scroll over a length of the passage, the nozzle aperture being formed in the wall of the passage.

The or each primary nozzle may be of a convergent-divergent geometry internally thereof, and in practice the nozzle is configured to give the supersonic flow of transport fluid into the mixing chamber. For a given steam condition, i.e. dryness, pressure and temperature, the nozzle is preferably configured to provide the highest velocity steam jet, the lowest pressure drop and the highest enthalpy. However, it is envisaged that the flow of transport fluid into the mixing chamber may alternatively be sub-sonic in some applications for application or process requirements, or transport fluid and/or working fluid property requirements.

The secondary nozzle may be of a convergent-divergent geometry internally thereof, and the nozzle may be configured to give the supersonic flow of transport fluid into the mixing chamber. For a given steam condition, i.e. dryness, pressure and temperature, the nozzle is preferably configured to provide the highest velocity steam jet, the lowest pressure drop and the highest enthalpy. However, it is envisaged that

the flow of transport fluid into the mixing chamber may alternatively be sub-sonic in some applications for application or process requirements, or transport fluid and/or working fluid property requirements.

For example only, and not by way of limitation, an optimum area ratio for the primary nozzle, namely exit area: throat area, lies in the range 1.75 and 15.0.

The or each primary nozzle is conveniently angled towards the flow from the fluid nozzles since this occasion's penetration of the working fluid. The angular orientation of the primary and fluid nozzles is selected for optimum performance which is dependent inter alia on the nozzles orientation and the internal geometry of the mixing chamber. Moreover, the creation of turbulence, governed inter alia by the angular orientation of the nozzle, is important to achieve optimum performance by dispersal of the working fluid in order to increase acceleration by momentum transfer and mass transfer. For example, and not by way of limitation, in the present invention it has been found that an angular orientation for the or each primary nozzle may lie in the range 0 to 30° to the local flow of working fluid.

The mixing chamber geometry is determined by the desired and projected output performance and to match the designed steam conditions and nozzle geometry. In this respect it will be appreciated that there is a combinatory effect as between the various geometric features and their effect on performance, namely droplet size, droplet density, mist spray cone angle and projected distance.

The cross-sectional area of the mixing chamber may vary with length and may have differing degrees of reduction or expansion along its length, i.e. the mixing chamber may taper at different angles at different points along its length. The mixing chamber may taper from the location of the or each primary nozzle and the taper ratio may be selected such that the generated mist spray velocity and trajectory is maintained at its optimum or desired position.

The mixing chamber of the present invention may be of variable length in order to provide a control on the droplet formation parameters i.e. droplet size, velocity and spray cone angle. The length of the mixing chamber is thus chosen to provide the optimum performance regarding momentum transfer. In some expressions of the invention the length may be adjustable in situ rather than pre-designed in order to provide a measure of versatility.

A cowl may be provided downstream of the outlet from the mixing chamber in order to further control the mist spray cone angle and projected distance. The cowl may comprise of a number of separate sections arranged in the radial direction, each section controlling and re-directing a portion of the mist spray emerging from the outlet of the mist generator.

The mist generator may be positioned within a further cowl which envelopes the mist generator in order to allow another fluid or fluids, for example air, to be entrained through the gap between the external wall of the mist generator and the internal wall of the cowl.

The fluid inlet or inlets which may be provided in the passage may be used for the introduction of gases or liquids or of other additives that may for example be treatment substances for the working fluid or may be particulates in powder or pulverulent form to be mixed with the working fluid. For example, water may be introduced via a fluid inlet or inlets for water mist applications. The fluids or other additives are entrained into the mist generator by the low pressure created within the unit. The fluids or additives can also be pressurised by an external means and pumped into the mist generator, if so required.

The fluid inlet or inlets may be of a form to correspond with the shape of the passage and/or the transport fluid nozzle and thus for example a circular passage would advantageously be provided with an annular fluid inlet or inlets circumscribing it.

In the case of a rectilinear passage, which may have a large width to height ratio, a fluid inlet or inlets would be provided at least on each transverse wall, but not necessarily on the sidewalls, although the invention optionally contemplates a full circumscription of the passage by the fluid inlet irrespective of shape.

The or each fluid inlet may be continuous or may be discontinuous in the form of a plurality of apertures, e.g. segmental, or a series of holes, arranged in a circumscribing pattern that may be circular. Each aperture may be provided with helical vanes formed in order to give in practice a swirl to the flow of the working fluid. As a further alternative the fluid inlet or inlets may circumscribe the passage in the form of a continuous helical scroll over a length of the passage, the fluid inlet aperture being formed in the wall of the passage.

According to a further aspect of the present invention a method of creating and moving a mist includes presenting a substantially circumscribing stream of working fluid, possibly formed from a mixture of one or more different liquids and gasses and/or powders, to a mist generator, the generator having a mixing chamber, applying a substantially circumscribing stream of transport fluid to the mixing chamber through an annular primary nozzle, the creation of a droplet mist spray from the interaction between the transport fluid and the working fluid, inducing the flow of the droplet spray through the outlet thereof, and modulating the shearing mechanism to vary the droplet mist discharge from the outlet.

The transport fluid is preferably a compressible fluid and may be a hot gas or vapour, for example steam.

According to a further aspect of the present invention a method of creating and moving a mist includes presenting a substantially circumscribing stream of working fluid, possibly formed from a mixture of one or more different liquids and gasses and/or powders, to a mist generator, the generator having a mixing chamber, applying

a substantially circumscribing stream of steam to the mixing chamber through an annular primary nozzle, the creation of a droplet mist spray from the interaction between the steam and the working fluid, inducing the flow of the droplet spray through the outlet thereof, and modulating the shearing mechanism to vary the droplet mist discharge from the outlet.

The method of the present invention involves the transfer of energy to the working fluid by momentum transfer (plus mass transfer for hot transport fluids such as steam) as the transport fluid is accelerated to supersonic speeds and directed by the primary nozzle into the working fluid. The resulting high velocity mixture of the transport and working fluid exits via the outlet.

According to a further aspect of the present invention a method of creating and moving a mist includes presenting a substantially circumscribing stream of working fluid, possibly formed from a mixture of one or more different liquids and gasses and/or powders, to a mist generator, the generator having a mixing chamber, applying a substantially circumscribing stream of transport fluid to the mixing chamber through an annular primary nozzle, applying a second stream of transport fluid to the mixing chamber through a central secondary nozzle, the creation of a droplet mist spray from the interaction between the transport fluid from the primary nozzle and the working fluid, transport fluid issuing from the primary and secondary nozzles inducing the flow of the droplet spray through the outlet thereof, and modulating the shearing mechanism to vary the droplet mist discharge from the outlet.

According to a further aspect of the present invention a method of creating and moving a mist includes presenting a substantially circumscribing stream of working fluid, possibly formed from a mixture of one or more different liquids and gasses and/or powders, to a mist generator, the generator having a mixing chamber, applying a substantially circumscribing stream of steam to the mixing chamber through an annular primary nozzle, applying a second stream of steam to the mixing chamber through a central secondary nozzle, the creation of a droplet mist spray from the

interaction between the steam from the primary nozzle and the working fluid, steam issuing from the primary and secondary nozzles inducing the flow of the droplet spray through the outlet thereof, and modulating the shearing mechanism to vary the droplet mist discharge from the outlet.

In carrying out the method of the present invention the creation and intensity of the dispersed droplet flow is occasioned by the design of the primary nozzle, or the primary and secondary nozzles, interacting with the setting of the desired parametric conditions, for example in the case of steam as the transport fluid the pressure, the dryness or steam quality, the temperature and the flow rate to achieve the required performance of the steam nozzle or nozzles.

The treatment of the working fluid, for example mixing, dispersing and projecting etc may occur in a single unit using one or more steam and/or fluid nozzles or by way of an in-line configuration using one or more mist generators as required.

The water mist generator of the present invention may be employed in a variety of applications ranging from fire extinguishing, suppression and control to smoke or particle wetting. In its application to fire extinguishing, suppression and control, a variety of working fluids may be moved and may include liquids, liquids with particles in suspension, and the like. It is an advantage of the relatively large bore of the passage of the generator, and the relatively large fluid nozzle geometries, that it can accommodate material that might find its way into the fluid inlet. It is a feature of the present invention that it is far more tolerant of the water quality used than conventional water mist systems which depend on small orifices and close tolerance nozzles.

The invention may also be used for mixing, dispersion or hydration and again the shearing mechanism provides the mechanism for achieving the desired result. In this connection the mist generator may be used for mixing one or more fluids, one or more fluids and solids in particulate form, for example powders. The fluids may be

in liquid or gaseous form. This mechanism could be used for example in the fighting of forest fires, where powders and other additives, such as fire suppressants, can be entrained, mixed and dispersed with the mist spray.

In this area of usage also lies another potential application in terms of foam generation for fire fighting purposes. The separate fluids, for example water, a foaming agent, and possibly air, are mixed within the mist generator using the transport fluid, e.g. steam, by virtue of the shearing effect.

Additionally, in fire or other high temperature environments the high density fine droplet mist generated by the mist generator provides a thermal barrier for people and fuel. In addition to reducing heat transfer by convection and conduction by cooling the air and gasses between the heat source and the people or fuel, the dense mist also reduces heat transfer by radiation. This has particular, but not exclusive, application to fire and smoke suppression in road, rail and air transport, and may greatly enhance passenger post-crash survivability.

The fine droplet mist generated by the present invention may be employed for general cooling applications. For example, the high cooling rate and low water quantities used provide the mechanism for cooling of industrial machinery and equipment. Alternatively, a very fine droplet mist may be utilized for cooling and humidifying areas or spaces, either indoors or outdoors, for the purpose of providing a more habitable environment for people or animals.

Alternatively, the mist generator may be employed either indoors or outdoors for general watering applications, for example, the watering of the plants inside a greenhouse. The water droplet size and distribution may be controlled to provide the appropriate watering mechanism, i.e. either root or foliage wetting, or a combination of both. In addition, the humidity of the greenhouse may also be controlled with the use of the mist generator.

The mist generator may be used in an explosive atmosphere to provide explosion prevention. The mist cools the atmosphere and dampens any airborne particulates, thus reducing the risk of explosion. Additionally, due to the high cooling rate and wide droplet distribution afforded by the fine droplet mist the mist generator may be employed for explosion suppression, particularly in a contained volume.

Alternatively, if a fire in a contained volume has burnt most of the available oxygen, a water mist may be introduced. This helps to extinguish the remaining fire without the risk of adding more oxygen. In a further alternative, an inert gas may be entrained into the mist generator, mixed with a liquid such as water and introduced onto the fire or hot volume.

Using a hot compressible transport fluid, such as steam, may provide an additional advantage of providing control of harmful bacteria. The shearing mechanism afforded by the present invention coupled with the heat input of the steam destroys the bacteria in the fluid flow, thereby providing for the sterilization of the working fluid. The sterilising effect could be enhanced further with the entrainment of chemicals or other additives which is mixed into the working fluid. This may have particular advantage in applications such as fire fighting, where the working fluid, such as water, is advantageously required to be stored for some time prior to use. During operation, the mist generator effectively sterilizes the water, destroying bacterium such as legionella pneumophila, during the droplet creation phase, prior to the water mist being projected from the mist generator.

The fine droplet mist produced by the mist generator might be advantageously employed where there has been a leakage or escape of chemical or biological materials in liquid or gaseous form. The atomised spray provides a mist which effectively creates a blanket saturation of the prevailing atmosphere giving a thorough wetting result. In the case where chemical or biological materials are involved, the mist wets the materials and occasions their precipitation or neutralization. Additional treatment could be provided by the introduction or

entrainment of chemical or biological additives into the working fluid. For example disinfectants may be entrained or introduced into the mist generator, and introduced into a room to be disinfected in a mist form. For decontamination applications no pre-mix of the chemicals is required as the chemicals can be entrained directly into the unit and mixed simultaneously. This greatly reduces the time required to start decontamination and also eliminates the requirement for a separate mixer and holding tank.

The mist generator may be deployed as an extractor whereby the injection of the transport fluid, for example steam, effects induction of a gas for movement from one zone to another. In this application the gas to be extracted is entrained into the generator through a fluid inlet. One example of use in this way is to be found in fire fighting when smoke extraction at the scene of a fire is required. The present invention has the additional benefit of wetting or quenching of explosive or toxic atmospheres utilising either just the steam, or with additional entrained water and/or chemical additives. The latter configuration could be used for placing the explosive or toxic substances into solution for safe disposal.

Further the mist generator may be employed to suppress or damp down particulates from a gas. This usage has particular, but not exclusive, application to smoke and dust suppression from a fire. Additional chemical additives in fluid and/or powder form may be entrained and mixed with the flow for treatment of the gas and/or particulates.

Further the mist generator may be employed for scrubbing particulate materials from a gas stream, to effect separation of the wanted from the waste elements. Again, the gas stream may be entrained into the mist generator through a fluid inlet nozzle. Additional chemical additives in fluid and/or powder form may be entrained and mixed with the flow for treatment of the gas and/or particulates. This usage has particular, but not exclusive, application to industrial exhaust scrubbers and dust extraction systems.

The use of the mist generator is not limited to the creation of water droplet mists. The mist generator may be used in many different applications which require a fluid to be broken down into a fine droplet mist. For example, the mist generator may be used to atomise a fuel, such as fuel oil, for the purpose of enhancing combustion. In this example, using steam as the transport fluid and a liquid fuel as the working fluid produces a finely dispersed mixture of fine fuel droplets and water droplets. It is well known in the art that such a mixture when combined with oxygen provides for enhanced combustion. In this example, the oxygen, possibly in the form of air, could also be entrained, mixed with and projected with the fuel/steam mist by the mist generator. Alternatively, a different transport fluid could be used and water or another fluid can be entrained and mixed with the fuel within the mist generator.

Alternatively, using a combustible fuel and air as the working fluids, but with a source of ignition at the exit of unit, the mist generator may be employed as a space heater or even a flame thrower device.

Further, the mist generator may be employed as an incinerator or process heater. In this example, a combustible fluid, for example propane, may be used as the transport fluid, introduced to the mist generator under pressure. In this example the working fluid may be an additional fuel or material which is required to be incinerated. Interaction between the transport fluid and working fluid creates a well mixed droplet mist which can be ignited and burnt in the mixing chamber or a separate chamber immediately after the outlet. Alternatively, the transport fluid can be ignited prior to exiting the primary and/or secondary nozzles, thereby presenting a high velocity and high temperature flame to the working fluid.

The mist generator affords the ability to create droplets comprised of a multi fluid emulsion. The droplets may comprise a homogeneous mix of different fluids, or may be formed of a first fluid droplet coated with an outer layer or layers of a second or more fluids. For example, the mist generator may be employed to create a fuel/water

emulsion droplet mist may be created for the purpose of further enhancing combustion. In this example, the water may either be separately entrained into the mist generator, or provided by the transport fluid itself, for example from the steam condensing upon contact with the working fluid. Additionally, the oxygen required for combustion, possibly in the form of air, could also be entrained, mixed with and projected with the fuel/steam mist by the mist generator.

The mist generator may be employed for low pressure impregnation of porous media. The working fluid or fluids, or fluid and solids mixture being dispersed and projected onto a porous media, so aiding the impregnation of the working fluid droplets into the material.

The mist generator may be employed for snow making purposes. This usage has particular but not exclusive application to artificially snow generation for both indoor and outdoor ski slopes. The fine water droplet mist is projected into and through the cold air whereupon the droplets freeze and form a frozen droplet 'snow'. This cooling mechanism may be further enhanced with the use of a separate cooler fitted at the outlet of the mist generator to enhance the cooling of the water mist. The parametric conditions of the mist generator and the transport fluid and working fluid properties and temperatures are selected for the particular environmental conditions in which it is to operate. Additional fluids or powders may be entrained and mixed within the mist generator for aiding the droplet cooling and freezing mechanism.

The high velocity of the water mist spray may advantageously be employed for cutting holes in compacted snow or ice. In this application the working fluid, which may be water, may advantageously be preheated before introduction to the mist generator to provide a higher temperature droplet mist. The enhanced heat transfer with the impact surface afforded by the water being in a droplet form, combined with the high impact velocity of the droplets provide a melting/cutting action through the compacted snow or ice. The resulting waste water from this cutting operation is either driven by the force of the issuing water mist spray back out through the hole which

has been cut, or in the case of compacted snow may be driven into the permeable structure of the snow. Alternatively, some or all of the waste water may be introduced back into the mist generator, either by entrainment or by being pumped, to provide or supplement the working fluid supply. The mist generator may be moved towards the 'cutting face' of the hole as the depth of the hole increases. Consequently, the transport fluid and the water may be supplied to the mist generator co-axially, to allow the feed supply pipes to fit within the diameter of the hole generated. The geometry of the nozzles, the mixing chamber and the outlet of the mist generator, plus the properties of the transport fluid and working fluid are selected to produce the required size of hole in the snow or ice, and the rate of cutting and water removal.

The performance of the present invention can be complimented with the choice of materials from which it is constructed. Although the chosen materials have to be suitable for the temperature, steam pressure and working fluid, there are no other restrictions on choice.

By way of example, seven embodiments of a mist generator in accordance with the present invention are described below with reference to the accompanying drawings in which:

Figure 1 is a cross sectional elevation of a first embodiment;
Figure 2 is a cross sectional elevation of a second embodiment;
Figure 3 is a cross sectional elevation of a third embodiment;
Figure 4 is a cross sectional elevation of a fourth embodiment; and
Figure 5 is a cross sectional elevation of a fifth embodiment
Figure 6 is a cross sectional elevation of a sixth embodiment.
Figure 7 is a cross sectional elevation of a seventh embodiment

Like numerals of reference have been used for like parts throughout the specification. In these examples steam is used as the transport fluid and water the liquid to be dispersed.

Referring to Figure 1 there is shown a mist generator 1 comprising a housing 2, providing a chamber 10 at its centre, an inlet 3, a fluid inlet 4 and an outlet 5.

A protrusion 6 extends into the housing 2 and defines exteriorly thereof a plenum 8 for the introduction of a transport fluid, the plenum 8 being provided with an inlet 3. The distal end 12 of the protrusion 6 is tapered on its relatively outer surface at 14 and defines an annular nozzle 16 between it and a correspondingly tapered part 18 of the inner wall of the housing 2, the nozzle 16 being in flow communication with the plenum 8. A fluid inlet 4 and plenum 24 are provided in the housing 2, together with a further annular nozzle 26 formed at a location coincident with that of the nozzle 16. The nozzle 16 is so shaped as in use to give supersonic flow.

In operation the fluid inlet 4 is connected to a source of a working fluid to be dispersed and would be a liquid, for example water, or a mixture of liquid or liquids and gas or gasses and/or powder or powders. Introduction of the steam into the mist generator 1 through the inlet 3, plenum 8 causes a jet of steam to issue forth through the nozzle 16. The parametric characteristics of the steam are selected whereby in use the steam issues from the nozzles at supersonic speeds into a mixing region of the chamber 10, herinafter described as the mixing chamber 9. The steam jet issuing from the nozzle 16 impacts the working fluid with high shear forces, thus atomising the water into droplets and occasioning induction of the resulting water mist through the mixing chamber 9 towards the outlet 5.

Figure 2 shows a second embodiment similar to that illustrated in Figure 1 save that the protrusion 6 incorporates a parallel axis aligned secondary nozzle 22. The inlet 3a is formed at the front end of the protrusion 6 extending into the housing incorporating interiorly thereof a plenum 7 for the introduction of a transport fluid. The plenum 7 is in flow communication with the plenum 8 through one or more channels 11. The distal end 12 of the protrusion 6 remote from the inlet 3a is tapered on its internal surface at 20 and defines a parallel axis aligned secondary nozzle 22, the nozzle 22

being in flow communication with the plenum 7. The nozzle 22 may be so shaped as in use to give supersonic flow into the mixing chamber 9.

In operation the fluid inlet 4 is connected to a source of a working fluid to be dispersed and would be a liquid, for example water, or a mixture of liquid or liquids and gas or gasses and/or powder or powders. Introduction of the steam into the mist generator 1 through the inlet 3a, plenums 7 and 8 causes a jet of steam to issue forth through the nozzles 16 and 22. The parametric characteristics of the steam are selected whereby in use the steam issues from the nozzles at supersonic speeds into the mixing chamber 9. The steam jet issuing from the nozzle 16 impacts the working fluid from the fluid nozzle 26 with high shear forces, thus atomising the water into droplets. The steam jets issuing from the nozzles 16 and 22 occasioning induction of the resulting water mist through the mixing chamber 9 towards the outlet 5.

Figure 3 shows a third embodiment similar to that illustrated in Figure 2 save that an additional transport fluid inlet 30 and plenum 32 are provided in the housing 2, together with a further annular nozzle 34 formed at a location coincident with that of the fluid inlet nozzle 26, thus providing a co-annular nozzle arrangement. The nozzle 34 is so shaped as in use to give supersonic flow into the mixing chamber 9. The exit angles of the steam nozzles 16 and 34 and the fluid inlet nozzle 26 are angled to provide the desired angles of interaction between the steam and water, and optimum energy transfer by momentum and mass transfer. In operation the high velocity steam jets issuing from the nozzles 16 and 34 impact the water with high shear forces, thus breaking the water into fine droplets and producing a well mixed 2 phase condition constituted by the liquid phase of the water and the steam. This both enhances the droplet formation by providing a double shearing action, and also provides a fluid separation or 'cushion' between the water and the walls of the mixing chamber 36. This prevents small water droplets being lost through coalescence on the internal walls of the mixing chamber 36 before exiting the mist generator via the outlet 5. Additionally the steam nozzles 16, 34 and 22 are angled and shaped to provide the desired spray mist dispersion angle and projection range. In this instance,

the energy transfer mechanism of momentum and mass transfer occasion's projection of the spray mist through the mixing chamber 9 and out of the outlet 5.

Figure 4 shows a fourth embodiment similar to that illustrated in Figure 2 save that it is provided with a diverging mixing chamber 9. This embodiment is also shown with a radial inlet 3 for the transport fluid rather than the parallel axis inlet 3a shown in Figure 2. However, either inlet type may be used.

The exit angles of the transport fluid nozzle 16 and the fluid inlet 26 are also angled to provide the desired angles of interaction between the transport and working fluid occasioning the optimum energy transfer by momentum and mass transfer.

In operation the arrangement illustrated provides a more diffuse or wider spray cone angle and therefore a wider mist coverage. The angle of the walls 36 of the mixing chamber relative to the centerline of the generator, and the incidence angles of the nozzles 16 and 26 relative to the walls 36, may be varied to provide different droplet sizes, spray cone angles and projection ranges. In an alternative embodiment, not shown, the mixing chamber 9 may be converging. This will provide a narrow concentrated mist spray, and may provide a greater axial velocity for the mist and therefore a greater projection range.

Referring now to Figure 5 which shows a fifth embodiment which is similar to a combination of embodiments illustrated in figures 3 and 4. Again an additional transport fluid inlet 30 and plenum 32 are provided in the housing 2, together with a further annular nozzle 34 formed at a location coincident with that of the fluid inlet nozzle 26, thus providing a co-annular nozzle arrangement. The nozzle 34 is so shaped as in use to give supersonic flow.

Again, this embodiment is provided with a diverging mixing chamber section 9 and the exit angles of the steam nozzles 16 and 34 and the fluid inlet 26 are also angled to provide the desired angles of interaction between the transport and working fluid,

thus occasioning the optimum energy transfer by momentum and mass transfer. The arrangement illustrated provides a more diffuse or wider spray cone angle and therefore a wider mist coverage. The angle of the walls 36 of the mixing chamber 9 relative to the centerline of the generator, and the incidence angles of the nozzles 16, 26 and 34 relative to the walls 36, may be varied to provide different droplet sizes, spray cone angles and projection ranges. In an alternative embodiment, not shown, the mixing chamber 9 may be converging. This will provide a narrow concentrated mist spray, and may provide a greater axial velocity for the mist and therefore a greater projection range.

In operation the two high velocity streams of steam exiting their respective nozzles 16 and 34, 'sandwich' the water stream exiting the fluid nozzle 26. This both enhances the droplet formation by providing a double shearing action, and also provides a fluid separation or 'cushion' between the water and the walls of the mixing chamber 36. This prevents small water droplets being lost through coalescence on the internal walls of the mixing chamber 36 before exiting the mist generator via the outlet 5.

Referring now to Figure 6 which shows a sixth embodiment. The transport fluid inlet 3a and plenum 7 are provided in the housing for the introduction of a transport fluid. A protrusion 38 at the end of the plenum 7 is tapered on its relatively outer surface at 18 and defines an annular nozzle 16 between it and a correspondingly tapered part 18 of the inner wall of the housing 2, the nozzle 16 being in flow communication with the plenum 7. A fluid inlet 4 and plenum 24 are provided in the housing 2, together with a further annular nozzle 26 formed at a location coincident with that of the nozzle 16. The nozzle 16 is so shaped as in use to give supersonic flow.

Again, this embodiment is provided with a diverging mixing chamber section 9 and the exit angles of the steam nozzle 16 and the fluid nozzle 26 are also angled to provide the desired angles of interaction between the transport and working fluid, thus occasioning the optimum energy transfer by momentum and mass transfer. The

arrangement illustrated provides a diffuse or wide spray cone angle and therefore a wider mist coverage. The angle of the walls 36 of the mixing chamber 9 relative to the centerline of the generator, and the incidence angles of the nozzles 16 and 26 relative to the walls 36, may be varied to provide different droplet sizes, spray cone angles and projection ranges. In an alternative embodiment, not shown, the mixing chamber 9 may be converging. This provides a narrow concentrated mist spray, a greater axial velocity for the mist spray and therefore a greater projection range.

Figure 7 shows a seventh embodiment similar to that illustrated in Figure 6 save that the protrusion 38 incorporates a parallel axis aligned secondary nozzle 22, the nozzle 22 being in flow communication with the plenum 7. The nozzle 22 may be so shaped as in use to give supersonic flow into the mixing chamber 9.

In operation the fluid inlet 4 is connected to a source of a working fluid to be dispersed and would be a liquid, for example water, or a mixture of liquid or liquids and gas or gasses and/or powder or powders. Introduction of the steam into the mist generator 1 through the inlet 3a, plenum 7, causes jets of steam to issue forth through the nozzles 16 and 22. The parametric characteristics of the steam are selected whereby in use the steam issues from the nozzles at supersonic speeds into the mixing chamber 9. The steam jet issuing from the nozzle 16 impacts the working fluid from the fluid nozzle 26 with high shear forces, thus atomising the water into droplets. The steam jets issuing from the nozzles 16 and 22 occasioning induction of the resulting water mist through the mixing chamber 9 towards the outlet 5. The angle of the walls 36 of the mixing chamber 9 relative to the centerline of the generator, and the incidence angles of the nozzles 16 and 26 relative to the walls 36, may be varied to provide different droplet sizes, spray cone angles and projection ranges.

With reference to the embodiments illustrated in figures 1 to 7, the flow rate, velocity and temperature of the working fluid, for example water, introduced to the fluid inlet nozzle 26 can be regulated to give the required intensity of shearing and droplet formation. The flow rate and velocity of the water being controllable by either an

external pressure regulation means, or by the gap size employed within the fluid inlet nozzle 26.

Although figures 2,3,6, and 7 illustrate a transport fluid inlet 3a located in a parallel axis location feeding transport fluid directly into plenum 7, it is envisaged that the transport fluid may be introduced through alternative locations, for example through a radial inlet such as inlet 3 as illustrated in figures 1, 4 and 5 which in turn may feed either or both plenums 7 and 8 directly, or through an alternative parallel axis location feeding directly into plenum 8 rather than plenum 7 (not shown). Additionally the fluid inlet 4 may alternatively be positioned in a parallel axis location (not shown), feeding working fluid along the body to the plenum 24. It is envisaged that any combination of derivatives shown in Figures 1 to 7 may be adopted.

In all embodiments, the fluid inlet nozzle 34 or another fluid inlet nozzle or nozzles may alternatively form the inlet for other fluids, or solids in flowable form such as a powder, for use in mixing or treatment purposes. For example, a further fluid inlet nozzle may be provided in the passage to provide chemical treatment of the working fluid, such as a fire retardant, if necessary. The placement of the fluid inlet nozzles may be either upstream or downstream of the transport fluid nozzle or where more than one fluid inlet nozzle is provided the placement may be both upstream and downstream dependent upon requirements.

Referring to embodiments 1 to 7, for use in applications of fire suppression in a room or other contained volume, the mist generator may be either located entirely within a volume or room containing a fire, or located such that only the exit 5 protrudes into the volume.

The mist generator has a number of fundamental advantages over conventional water mist systems in that the mechanism of droplet formation is controlled by a number of adjustable parameters. This provides accurate control of the amount of water used,

the droplet size, the spray cone angle and the projected range of the mist. For example, a water mist generator using steam as the transport fluid can produce a water mist with a high percentage of water droplets in the 40-50μm size range, with an adjustable spray cone angle and a projected range of over 40m.

The mist generator can be used for either short burst operation of continuous running. As there are no moving parts in the system, and the mist generator is not dependent on small sized and closely toleranced fluid inlet nozzles there is very little maintenance required. It is known that due to the small orifice size and high water pressures used by some of the existing water mist systems that nozzle wear is a major issue with these systems. In addition, due to the use of relatively large fluid inlet nozzles in the mist generator it is less sensitive to poor water quality. In cases where the mist generator is to be used in a marine environment, even sea water may be used.

The mist generator has an advantage for use in potentially explosive atmospheres as it has no moving parts or electrical wires or circuitry and therefore has no source of ignition.

Although the mist generator may use a hot compressible transport fluid such as steam, this system is not to be confused with existing steam flooding systems which produce a very hot atmosphere. In the current invention, the heat transfer between the steam and the working fluid results in a relatively low water mist temperature. For example, the exit temperature within the mist at the point of exit 5 has been recorded at less than 52°C, reducing through continued heat transfer between the steam and water to room temperature within a short distance. The exit temperature of the water mist is controllable by regulation of the steam supply conditions, i.e., flow rate, pressure etc, and the water flow rate conditions, i.e. flow rate, velocity and temperature. Droplet formation within the mist generator may be further enhanced with the entrainment of chemicals such as surfactants. The surfactants can be entrained directly into the mist generator and intimately mixed with the working fluid

at the point of droplet formation, thereby minimizing the quantity of surfactant required.

The ability of the mist generator to handle and process a range of working fluids provides advantages over many other mist generators. As to the droplet formation is achieved through high velocity shear and, in the case of steam as the transport fluid, mass transfer from a separate transport fluid, almost any working fluid can be introduced to the mist generator to be finely dispersed and projected. The working fluids can range from low viscosity easily flowable fluids and fluid/solids mixtures to high viscosity fluids and slurries. Even fluids or slurries containing relatively large solid particles can be handled. For example, the mist generator may be employed in applications such as spray painting, powder deposition, and grease and other protective coating spraying. This may have particular, although not exclusive, application in electro phoretic painting and spraying.

Additionally, the ability for the mist generator to handle powders and solid particles provides another potential application of spray drying. For example, a working fluid comprised of particles or solids in solution is dispersed and projected by the mist generator, preferably into a hot atmosphere. The liquid is evaporated from the mist, possibly aided by heat from a suitable hot transport fluid, thereby drying the particles or solids.

Due to the relatively low pressures involved in the present invention, the mist generator can be easily relocated and re-directed while in operation. Using appropriate flexible steam and water supply pipes the mist generator is easily man portable. It is also envisaged that the steam source could be chemically generated so providing the possibility that the whole system could become man-portable, possibly utilizing a back-pack arrangement.

It is this versatility that allows the present invention to be applied in many different applications over a wide range of operating conditions. Furthermore the shape of the

mist generator may be of any convenient form suitable for the particular application. Thus the mist generator may be circular, curvilinear or rectilinear, to facilitate matching of the mist generator to the specific application or size scaling. For example the mist generator could be made to fit a standard door letterbox to allow fire fighters to easily treat a house fire without the need to enter the building. Size scaling is important in terms of being able to readily accommodate differing designed capacities in contrast to conventional equipment.

Similarly, powders or other particles may be entrained or introduced into the mist generator, mixed with and dispersed with another fluid or fluids. The particles being dispersed with the other fluid or fluids, or wetted and/or coated or otherwise treated prior to being projected.

The present invention thus affords wide applicability with improved performance over the prior art proposals in the field of water mist generators